Original Article

A Survey of Atmospheric Pollen and Spores in North-Western Nigeria

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Abstract

The incidence of airborne pollen occurring as aeroallergens of varied levels at different periods of the year has generated some public health concern globally. The present study was conducted in order to examine the monthly depositional rate of airborne pollen and fern spores, as well as the impact of meteorological parameters and local plants on pollen distribution at two study sites in Kaduna and Sokoto States of North Western Nigeria. The study spanned a period of one year, during which a modified Tauber pollen sampler was employed in the collection of atmospheric pollen and fern spores; local plants were also enumerated. Residual solution was collected monthly, subjected to acetolysis and the treated residues were viewed for microscopic studies. The results reveal monthly distribution of airborne pollen and fern spore types at the study sites during the sampling period. Dominant pollen types in Kaduna State were those of *Alchornea laxiflora*, *Pinus caribaea*, *Terminalia* sp., Sapotaceae and Poaceae family. Pollen of *Syzygium guineense*, *Alchornea* sp., Sapotaceae and Poaceae dominated in Sokoto State. Spores of *Pteris* sp., *Nephrolepis* sp. and a trilete fern were also recovered at both locations. Some local plants in the immediate vegetation contributed to the aeroflora of these locations. No significant correlation was recorded between monthly total pollen concentrations and mean monthly meteorological parameters of the locations. It is imperative to investigate the allergenicity of these dominant pollen types, so as to aid pollen hypersensitive individuals in adopting appropriate prophylactic measures.

Keywords: airborne; allergenicity; dominant; local plants; meteorological

Introduction

The study of pollen grains, fungal spores, insect debris, dust mites and organic dust, dispersed into the atmosphere as particles of biological origin is referred to as aerobiology (Singh and Kumar, 2004). Information about the type and abundance of airborne pollen grains at a given time in an area could be obtained through the concept of aeropalynology. The allergen proteins of pollen are immunomodulatory substances, playing a crucial role in the sensitization and/or exacerbation of these allergies (D'Amato *et al.*, 2002; Kamijo *et al.*, 2013). The common symptoms of allergy hypersensitivity are bronchial asthma, atopic dermatitis, rhinoconjunctivitis and a general feeling of malaise, among others (Singh and Mathur, 2012).

In Nigeria, some aeropalynological work have been recently conducted in various parts of the country and these include investigating dominant pollen and fern spore types (Adekanmbi and Ogundipe, 2010; Adeonipekun, 2012; Abdulrahman *et al.*, 2015; Ajikah *et al.*, 2015, 2017; Adekanmbi *et al.*, 2017), examining correlations between pollen data and meteorological parameters (Ezike *et al.*, 2016; Ajikah *et al.*, 2017; Alebiosu *et al.*, 2017);

relationships between airborne pollen load and medical data (Adeniyi *et al.*, 2014); inferences on their health risk periods (Adeniyi *et al.*, 2014; Ezike *et al.*, 2016; Alebiosu *et al.*, 2017).

Essien and Aina (2014) quoted Singh and Rawat (2000), stating that most pollen grains found as allergens are wind-pollinated, characteristic of a light-weight and may be dispersed to considerable distances. They further cited that this feature makes them easily inhaled by humans, penetrating into the nasal mucosa.

However, there is still a dearth of information about the atmospheric distribution of pollen types and high-low risk periods for pollen allergy sufferers in Nigeria. Also, most aeropalynological studies have been conducted in the southern region, with little contributions from the North-central parts of the country but no record yet in other northern areas. This present study was carried out at selected study sites of North Western Nigeria, in order to examine the monthly depositional rate of airborne pollen and fern spores; investigate the effect of meteorological parameters on monthly airborne pollen load for a period of one year; observe the relationship between the recovered airborne pollen types and plants in the surrounding vegetation of the study sites.

Materials and Methods

Description of the study areas

The study sites are located in Kaduna and Sokoto States, geographically positioned in the semi-arid zone of North-western Nigeria. Kaduna State is located on the southern end of the high plains of northern Nigeria, bounded by parallels of latitude 9°02'N and 11°32'N, extending from the upper River Mariga on longitude 6°15'E of the Greenwich meridian on the foot slopes of the scarp of Jos Plateau. The rainy season has a short duration and occurs during the high sun period, followed by 5-7 months of dry season. The dry season is practically rainless and spans between October and April. The daily maximum temperatures show a major peak in April and a minor one in October. The mean minimum temperature rises from its lowest value of about 11 °C in December and January during harmattan, up to a high temperature of about 40 °C in July/August (Afolalu, 2009).

Sokoto State is located in the extreme part of this zone and geographically lies along latitude 13°05'N and longitude 05°15'E. They are characterized by strong seasonality in rainfall and temperature distribution (Fadele *et al.*, 2012; Yakubu *et al.*, 2013). The wet season starts from late May and ends in early September but could extend to October with a mean annual rainfall of between 500 mm and 1300 mm with a peak rainfall in August. Dry season starts from October with the cold, dry dust-laden harmattan wind lasting up till February. Between the months of March to May, the daily temperatures are hot and dry, reaching 38 °C - 42 °C with relative humidity of less than 20% (Ahmed and Egwu, 2014).

In the two study areas, the vegetation type consists of Northern Guinea savannah and Sudano-Sahelian savannah (Afolalu, 2009; Ahmed and Egwu, 2014). The prolonged dry season (6-9 months) sustain fewer trees and grasses than the Southern Guinea savannah. The vegetation has undergone a severe destruction in the process of land clearing for the cultivation of important economic crops such as cotton, millet, maize and wheat. This is in addition to the devastation due to animal husbandry, especially cattle rearing which is remarkably favoured in this belt because the area is relatively free from tse-tse fly. The trees of the Sudan savannah include *Acacia* spp., *Vitellaria paradoxa*, *Adansonia digitata* and *Ceiba pentandra*, as cited by Yakubu *et al.* (2013). It is characterized by abundant grasses of less than 3 m height (Fadele *et al.*, 2012) and few stunted trees often not taller than 15 m. The main soil type is the ferruginous tropical soil mostly formed from the crystalline metamorphic rocks of granite gneiss (Afolalu, 2009).

Study sites

Two study sites were selected for aerosampling in the North-western Nigeria (Fig. 1) and a global positioning system was used to determine the position of the sampling points; Ahmadu Bello University, Zaria, Kaduna State (Latitude 11.0667°N, Longitude 7.7000°E) and Usman Danfodiyo University, Sokoto State (Latitude 9.945954°N, Longitude 8.893007°E).

Plant enumeration

This involved a qualitative enumeration of local plants in the surrounding vegetation using a quadrat of 25 x 25 m plot for tree species and a quadrat of 1.0 x 1.0 m plot for both herbs and grasses. Samples were collected randomly within each plot and plants were identified with the aid of keys, following the works of Dalziel (1937), Hutchinson and Dalziel (1954, 1963), Keay (1959), Keay *et al.* (1964) and Keay (1989). Voucher specimens of identified plants were collected and deposited at the University of Lagos Herbarium.
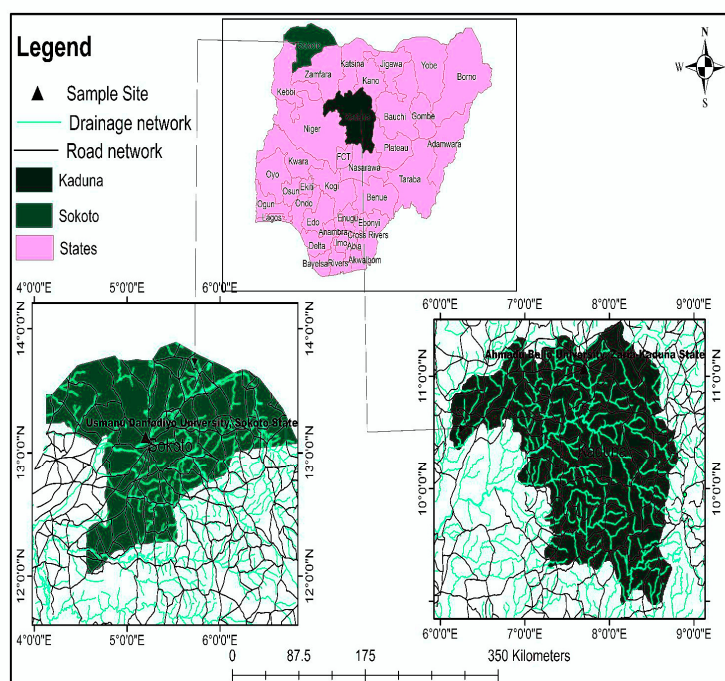

Fig. 1. Map of Nigeria showing the study sites in Kaduna and Sokoto States respectively

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Setting up of pollen samplers

A modified Tauber pollen sampler containing a solution of 50 ml glycerol (to prevent drying up of organic particles), 10 ml formaldehyde (to prevent the decay of dead organisms) and 5 ml phenol (to kill insects) was constructed for the trapping of airborne palynomorphs at each of the study locations (Fig. 2), following the procedures of Adekanmbi and Ogundipe, 2010, Ezike *et al.*, 2016 and Ajikah *et al.*, 2017. This sampler was placed at the height of 5 ft. above the ground level (ca. average human height) with a 10 cm ring fixed at the top of it. In order to prevent it from being blown away by the wind, it was well cemented with one foot buried underground to provide support.

Fig. 2. A modified Tauber sampler mounted at one of the two study sites

Sample collection

The collection of residual solution was done monthly and spanned from July 2015 to June 2016, covering rainy and dry seasons. The sampler was washed at the end of each monthly collection.

Treatment and microscopy

In order to separate the residues containing palynomorphs from supernatant fluids, the solutions were centrifuged at 2,500 rpm for 5 min. The residues were then subjected to acetolysis method of treatment following Erdtman (1969); preparation of acetolysis mixture involves an addition of concentrated sulphuric acid and acetic anhydride in the volume ratio of 1:9 respectively, 5 ml of the prepared mixture was added to each sample residue and heated in a water bath at 100 ºC for 10 min. The residues were centrifuged, decanted, rinsed with distilled water and this process was carried out twice. The residues were stored in vials with an addition of two drops of glycerine for their preservation. Slide preparation and microscopy of prepared residues were also done. Identification of palynomorphs was achieved with the aid of photomicrographs in reference journals including Sowunmi (1973; 1995), Adekanmbi (2009), Adekanmbi and Ogundipe (2009), Gosling *et al.* (2013) and unpublished albums. Photomicrographs of some pollen and fern spore types (Fig. 3) were taken using a Euromex digital camera attached to an Olympus light microscope.
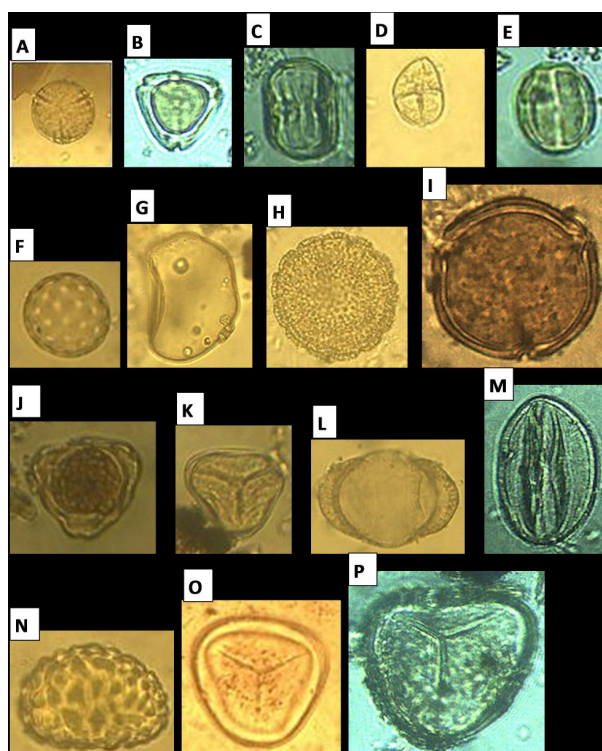
Fig. 3. Photomicrographs of some recovered pollen grains and fern spores in this study (A-M: Pollen grains; N-P: Fern spores); **A.** *Alchornea laxiflora.* **B.** *Syzygium guineense* **C.** *Terminalia* sp. **D.** *Mimosa* sp. **E.** *Lannea/Sclerocarya* sp. **F.** *Amaranthus* sp. **G.** Poaceae. **H.** *Borreria* sp. **I.** *Senna* sp. **J.** *Casuarina equisetifolia.* **K.** *Elaeis guineensis.* **L.** *Pinus caribaea.* **M.** *Vitex* sp. **N.** *Nephrolepis* sp. **O.** *Pteris* sp. **P.** Trilete fern. (All magnification: ×400 objective)

Meteorological data collection

Mean monthly data on air temperature, wind speed, relative humidity and rainfall for the sampling period in the study locations were sourced from the Nigerian Meteorological Agency, Oshodi, Lagos, Nigeria.

Correlation between monthly pollen concentrations and meteorological parameters

The relationship between monthly pollen concentrations and mean monthly meteorological data of the study locations was examined. Correlation coefficients were obtained by employing a Pearson correlation test at 95% confidence interval, using SPSS statistic version 23 package, since these statistical data are parametric.

Results

Palynological study

All 29 atmospheric pollen types belonging to 17 different plant families were recorded in Ahmadu Bello University, Zaria, Kaduna State, Nigeria. Among these, 11, 7 and 11 were identified to familial, generic and species levels respectively. The unidentified pollen types were designated as pollen indeterminate. An annual pollen concentration of 2,723 was observed in this location. The highest total pollen count was recorded in the month of October (25.30%) and a minimum in June (0.96%). In Usmanu Danfodiyo University, Sokoto State Nigeria, 30 pollen types belonging to 18 different plant families were recorded. Among these, 11, 13 and 6 were identified to familial, generic and species levels respectively. An annual pollen concentration of 3,839 was observed in this location. The highest total pollen count was observed in March (47.85%) and the lowest record in June (1.51%).

The most abundant pollen types in Kaduna State were produced by *Alchornea laxiflora*, *Pinus caribaea*, *Terminalia* sp., Sapotaceae and Poaceae. The most abundant pollen types in Sokoto State were produced by *Syzygium guineense*, *Alchornea* sp., Sapotaceae and Poaceae. 26 airborne pollen types were common to both locations; 89.66% of pollen types identified in Kaduna state were also recovered in Sokoto state; 86.67% of pollen types identified in Sokoto state were also recovered in Kaduna state. In Kaduna State, highest monthly fern spore concentration of 6 (28.57%) was observed in October and May respectively with no record in the months of July, August, December, January, February and March respectively. Of the three fern spore types recovered in this location, *Nephrolepis* sp. was the most abundantly represented, followed by *Pteris* sp. and a trilete fern spore respectively (Table 1). In Sokoto State, highest fern spore concentration of 35 (60.35%) was observed in the month of November, followed by 19 (32.76%) in the month of June. There was no record of fern spore count in the months of July, August, September, December, February and March respectively. A trilete fern spore was the most abundant, followed by *Pteris* sp. and *Nephrolepis* sp. respectively (Table 2). Monthly atmospheric pollen and fern spore concentrations of the study locations during the sampling period are presented in Tables 1 and 2.

Table 1. Frequency of atmospheric pollen and fern spores recovered from the study location in Kaduna State, Nigeria (July 2015 to June 2016)

S. no	Pollen types	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1.	*Alchornea laxiflora*	88	2	7	18	0	26	3	0	0	0	0	0	144
2.	Poaceae	1	65	271	494	32	0	92	82	6	4	5	11	1,063
3.	*Amaranthus* sp.	0	5	43	33	3	4	8	6	1	2	1	0	106
4.	Arecaceae	0	0	3	7	0	4	5	0	0	0	0	0	19
5.	*Vitex* sp. type	0	11	23	50	0	0	15	0	0	0	0	0	99
6.	*Syzygium guineense*	0	42	12	19	6	10	9	9	12	2	1	3	125
7.	*Terminalia* sp.	0	4	12	1	0	143	2	235	4	18	0	0	419
8.	*Casuarina equisetifolia*	0	5	24	29	0	1	0	1	0	0	0	0	60
9.	*Gomphrena celosoides*	0	0	1	0	0	0	0	1	0	10	0	0	12
10.	Euphorbiaceae	0	3	1	2	1	0	0	0	0	0	0	0	7
11.	Cyperaceae	0	6	10	12	0	0	1	0	0	0	0	0	29
12.	*Elaeis guineensis*	0	22	4	0	7	0	3	2	1	0	0	0	39
13.	*Tridax procumbens*	0	0	0	6	5	4	1	16	0	0	0	3	35
14.	Fabaceae	0	1	7	0	4	8	28	36	2	0	3	4	93

S. no	Pollen types	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
15.	Sapotaceae	0	0	2	0	0	0	3	8	7	12	8	0	40
16.	*Acacia* sp.	0	1	2	2	1	0	1	1	0	0	0	0	8
17.	*Lannea / Sclerocarya* sp.	0	0	0	1	0	0	1	0	2	1	0	0	5
18.	*Pinus caribbea*	0	0	1	0	21	1	145	104	15	4	3	1	295
19.	*Borreria* sp.	0	0	1	15	5	0	2	3	1	1	0	0	28
20.	Mimosaceae.	0	0	0	0	0	0	0	1	1	1	0	1	4
21.	*Asystasia gagentica*	0	0	0	0	0	0	0	0	0	0	0	2	2
22.	*Euphorbia heterophylla*	0	0	0	0	0	0	11	0	0	0	2	0	13
23.	*Nauclea latifolia* type	0	0	0	0	0	0	2	0	0	0	0	0	2
24.	*Hyphaene* sp.	0	0	0	0	0	0	15	0	2	2	0	0	19
25.	*Senna* sp.	0	0	0	0	0	0	10	0	4	15	4	1	34
26.	Convolvulaceae	0	0	0	0	0	0	1	0	0	0	0	0	1
27.	Asteraceae	0	0	0	0	0	0	11	0	1	3	4	0	19
28.	Pollen Indeterminate	0	0	0	0	0	0	2	0	0	0	1	0	3
	Total pollen count in each month	89	167	424	689	85	201	371	505	59	75	32	26	2,723
	%	3.27	6.13	15.57	25.30	3.12	7.38	13.63	18.55	2.17	2.75	1.18	0.96	
	Fern spore types													Total
30.	*Nephrolepis* sp.	0	0	1	4	0	0	0	0	0	2	1	1	9
31.	*Pteris* sp.	0	0	0	1	2	0	0	0	0	0	2	1	6
32.	Trilete fern spore	0	0	0	1	0	0	0	0	0	0	3	2	6
	Total fern spore count	0	0	1	6	2	0	0	0	0	2	6	4	21
	%	0.00	0.00	4.76	28.57	9.52	0.00	0.00	0.00	0.00	9.52	28.57	19.05	

Table 2. Frequency of atmospheric pollen and fern spores recovered from the study location in Sokoto State, Nigeria (July 2015 to June 2016)

S. no	Pollen types	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
1.	Poaceae	47	37	195	320	182	68	92	27	183	11	26	9	1,197
2.	Asteraceae	7	0	0	0	0	0	0	0	1	0	0	0	8
3.	*Terminalia* sp.	1	1	2	1	5	4	2	2	4	0	5	10	37
4.	*Borreria* sp.	0	0	6	0	0	0	0	0	4	0	2	0	12

No.	Type													Total
5.	*Vitex* sp. type	0	5	0	0	0	0	0	9	1	0	0	0	15
6.	Sapotaceae	0	1	0	1	2	2	7	3	149	125	20	0	310
7	*Mimosa* sp.	1	0	2	0	1	0	0	0	9	0	2	6	21
8.	*Syzygium guineense*	0	1	6	5	15	0	5	184	1,433	123	2	1	1,775
9.	*Alchornea* sp.	4	136	7	5	118	3	7	4	0	0	2	0	286
10.	*Amaranthus* sp.	0	3	11	3	5	2	0	0	3	0	0	0	27
11.	*Casuarina equisetifolia*	0	1	1	0	0	0	0	0	0	0	0	0	2
12.	Cyperaceae	0	1	2	3	1	0	0	0	0	0	0	0	7
13.	*Acacia* sp.	0	2	1	2	0	0	0	0	3	0	0	0	8
14.	*Tridax procumbens*	0	0	0	1	2	1	1	0	5	0	3	18	31
15.	*Elaeis guineensis*	0	0	0	0	27	0	3	0	0	0	1	0	31
16.	*Gomphrena celosoides*	0	0	0	0	0	0	0	0	3	1	0	0	4
17.	*Hyphaene* sp.	0	0	0	0	0	0	0	0	1	0	1	0	2
18.	*Senna* sp.	0	0	0	0	0	0	0	0	16	0	0	12	28
19.	*Calystegia* sp. type	0	0	0	0	0	0	0	0	2	0	0	0	2
20.	*Citrus* sp.	0	0	0	0	0	0	0	0	1	0	0	0	1
21.	*Uapaca* sp.	0	0	0	0	0	0	0	0	1	0	1	0	2
22.	*Nauclea* sp. type	0	0	0	0	0	0	0	0	3	1	0	0	4
23.	*Lannea / Sclerocarya* sp.	0	0	0	0	0	0	0	0	0	1	2	0	3
24.	Convolvulaceae	0	0	0	0	0	0	0	0	2	0	0	0	2
25.	Tiliaceae	0	0	0	0	0	0	0	0	1	0	0	0	1
26.	Fabaceae	2	0	0	0	1	0	0	0	0	2	0	0	5
27.	Arecaceae	0	0	0	0	1	0	0	0	5	0	1	0	7
28.	Euphorbiaceae	0	0	0	0	0	0	0	0	14	0	0	1	15
29.	Mimosaceae	0	0	0	0	0	0	0	0	0	2	0	1	3
30.	Pollen Indeterminate	0	0	0	0	0	0	0	0	2	0	0	0	2
	Total pollen count in each month	62	188	233	341	360	80	117	229	1837	266	68	58	3,839
	%	1.62	4.90	6.07	8.88	9.38	2.08	3.05	5.97	47.85	6.93	1.77	1.51	
	Fern spore types													Total
32.	*Nephrolepis* sp.	0	0	0	1	6	0	1	0	0	0	0	3	11
33.	*Pteris* sp.	0	0	0	0	13	0	0	0	0	1	0	8	22
34.	Trilete fern spore	0	0	0	0	16	0	0	0	0	0	1	8	25
	Total fern spore count	0	0	0	1	35	0	1	0	0	1	1	19	58
	%	0.00	0.00	0.00	1.72	60.35	0.00	1.72	0.00	0.00	1.72	1.72	32.76	

Vegetation description and meteorological data of the study locations

The vegetation in Ahmadu Bello University, Zaria, Kaduna State is a northern guinea savannah type with sparsely distributed trees and also dominated by shrubs. The vegetation in Usmanu Danfodiyo University, Sokoto State is a typical Sahel savannah type with sparsely dispersed trees, characterized by a fissured thick bark layer. The entire vegetation predominantly consists of unidentified grasses which do not exceed a height of 1-2 cm. Identified plants in the study locations are listed in Tables 3 and 4. Variations were observed in the monthly mean values of meteorological parameters including air temperature, rainfall, relative humidity and wind speed at the study sites during the sampling period (Figs. 4-7).

Table 3. Enumerated plants around the study site in Ahmadu Bello University, Kaduna State

S. no	Scientific name	Family name	Habit
1.	*Pennisetum* sp.	Poaceae	Grass
2.	*Tridax procumbens* L.	Asteraceae	Herb
3.	*Ageratum conyzoides* L.	Asteraceae	Herb
4.	*Senna occidentalis* L.	Fabaceae	Shrub
5.	*Alchornea laxiflora* (Benth.) Pax & K. Hoffm.	Euphorbiaceae	Shrub
6.	*Albizia lebbeck* (L.) Benth.	Mimosaceae	Tree
7.	*Acacia sieberiana* DC.	Fabaceae	Tree
8.	*Azadirachta indica* A. Juss.	Meliaceae	Tree
9.	*Cassia sieberiana* DC.	Fabaceae	Tree
10.	*Cassia* sp.	Fabaceae	Tree
11.	*Acacia seyal* Del.	Fabaceae	Tree
12.	*Pinus caribaea* Morlet.	Pinaceae	Tree
13.	*Khaya grandifoliola* (Welw.) C.DC.	Meliaceae	Tree
14.	*Cyperus* sp.	Cyperaceae	Sedge

Table 4. Enumerated plants around the study site in Usmanu Danfodiyo University, Sokoto State

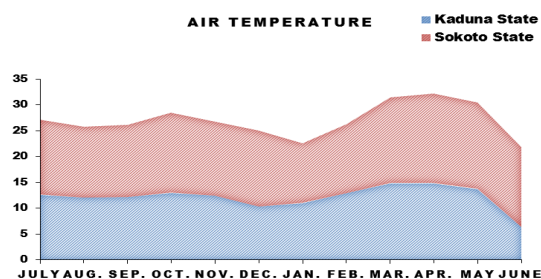| S. no	Scientific name	Family names	Habit
1.	*Tridax procumbens* L.	Asteraceae	Herb
2.	*Euphorbia hirta* L.	Euphorbiaceae	Shrub
3.	*Sclerocarya birrea* (A Rich.) Hochst.	Anacardiaceae	Tree
4.	*Diospyros mespiliformis* (Hochst. ex A.DC.)	Ebenaceae	Tree
5.	*Azadirachta indica* A. Juss.	Meliaceae	Tree
6.	*Borassus aethiopium* Mart.	Arecaceae	Tree

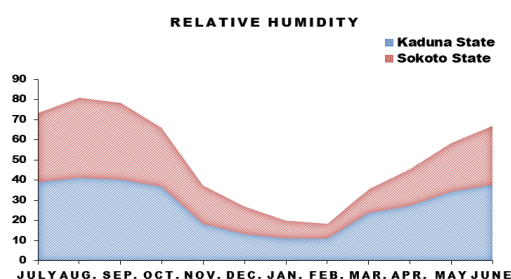Fig. 4. Mean monthly air temperature values (°C) in Kaduna and Sokoto States

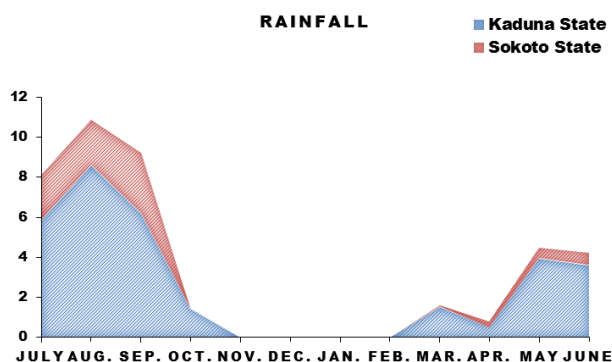Fig. 5. Mean monthly relative humidity values (%) in Kaduna and Sokoto States

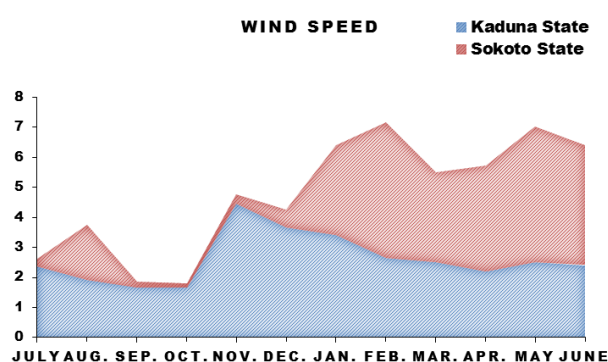Fig. 6. Mean monthly rainfall values (mm) in Kaduna and Sokoto States

Fig. 7. Mean monthly wind speed values (knot) in Kaduna and Sokoto States

Table 5. Relationship between monthly pollen concentrations and values of mean meteorological parameters at the study site in Kaduna state at 95% confidence interval (P < 0.05)

		Pollen concentration	Temperature	Wind speed	Relative humidity	Rainfall
Pearson correlation	Pollen concentration	1.000	-.240	-.374	.266	.009
	Temperature	-.240	1.000	-.421	.117	-.160
	Wind speed	-.374	-.421	1.000	-.741	-.523
	Relative humidity	.266	.117	-.741	1.000	.820
	Rainfall	.009	-.160	-.523	.820	1.000
Sig. (1-tailed)	Pollen concentration	.	.252	.143	.229	.490
	Temperature	.252	.	.113	.374	.330
	Wind speed	.143	.113	.	.007	.060
	Relative humidity	.229	.374	.007	.	.002
	Rainfall	.490	.330	.060	.002	.
N	Pollen concentration	10	10	10	10	10
	Temperature	10	10	10	10	10
	Wind speed	10	10	10	10	10
	Relative humidity	10	10	10	10	10
	Rainfall	10	10	10	10	10

Table 6. Correlation coefficients showing the significance levels in the correlation between monthly pollen concentrations and values of mean monthly meteorological parameters at the study site in Kaduna State at 95% confidence interval (P < 0.05)

Model	Unstandardized coefficients		Standardized coefficients			Correlations		
	B	Std. Error	Beta	T	**Sig.**	Zero-order	Partial	Part
(Constant)	2146.784	956.253		2.245	**.075**			
Temperature	-65.376	26.118	-.826	-2.503	**.054**	-.240	-.746	-.650
Wind speed	-94.789	52.733	-.803	-1.798	**.132**	-.374	-.627	-.467
Relative humidity	6.965	6.347	.650	1.097	**.322**	.266	.441	.285
Rainfall	-1.254	.592	-1.076	-2.119	**.088**	.009	-.688	-.550

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Table 7. Relationship between monthly pollen concentrations and values of mean meteorological parameters at the study site in Sokoto state at 95% confidence interval (P < 0.05)

		Pollen concentration	Temperature	Wind speed	Relative humidity	Rainfall
Pearson correlation	Pollen concentration	1.000	.088	.005	-.011	-.123
	Temperature	.088	1.000	-.694	.419	.286
	Wind speed	.005	-.694	1.000	-.595	-.452
	Relative humidity	-.011	.419	-.595	1.000	.949
	Rainfall	-.123	.286	-.452	.949	1.000
Sig. (1-tailed)	Pollen concentration	.	.426	.496	.490	.396
	Temperature	.426	.	.042	.175	.267
	Wind speed	.496	.042	.	.080	.155
	Relative humidity	.490	.175	.080	.	.001
	Rainfall	.396	.267	.155	.001	.
N	Pollen concentration	7	7	7	7	7
	Temperature	7	7	7	7	7
	Wind speed	7	7	7	7	7
	Relative humidity	7	7	7	7	7
	Rainfall	7	7	7	7	7

Table 8. Correlation coefficients showing the significance levels in the correlation between monthly pollen concentrations and values of mean monthly meteorological parameters at the study site in Sokoto state at 95% confidence interval (P < 0.05)

Model	Unstandardized coefficients		Standardized coefficients	T	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
(Constant)	-92.192	1278.517		-.072	**.949**			
Temperature	4.267	44.693	.087	.095	**.933**	.088	.067	.062
Wind speed	9.126	32.909	.294	.277	**.808**	.005	.192	.180
Relative humidity	5.271	9.579	1.419	.550	**.637**	-.011	.363	.357
Rainfall	-1.708	2.917	-1.362	-.585	**.618**	-.123	-.382	-.379

Discussion

The results of the present study reveal the atmospheric distribution of different pollen types recovered from the two sampling locations (Tables 1 and 2). Previous studies conducted in Nigeria have similarly employed the use of gravitational and non-volumetric samplers for the trapping of airborne pollen and spores (Njokuocha, 2006; Adekanmbi and Ogundipe, 2010; Essien and Aina, 2014; Adeniyi *et al.*, 2014; Ezike *et al.*, 2016; Ajikah *et al.*, 2017; Adekanmbi *et al.*, 2017; Alebiosu *et al.*, 2017). Higher monthly pollen concentrations were observed from October to March and this is similar to Njokuocha (2006) who reported more pollen load from September to January in Nsukka, South-Eastern, Nigeria. These findings are also supported by Ezike *et al.* (2016) who observed highest pollen abundance from October to January in Garki, Abuja, North-Central Nigeria, during which they designated these harmattan months as a period of higher risk for individuals that are hypersensitive to pollen grains. In contrast to these findings, Essien and Aina (2014) reported monthly pollen concentration to be more abundant in the month of May, followed by June.

It is noteworthy that a considerable similarity exists in the array of pollen types recovered from the two locations (Tables 1 and 2). This remarkable similarity may be attributed to a wide geographical diversity of parent plants producing these pollen types in vegetation both proximal and distal to the two study sites. Preponderant pollen types identified in this study are similar to Ajikah *et al.* (2015) who reported Combretaceae, Sapotaceae and Poaceae as major airborne pollen producers in their study. The dominant pollen recovery of *Pinus caribaea* in Kaduna State corresponds with Singh and Dahiya (2008), Scevkova *et al.* (2015) who identified a species of *Pinus* as one of the most abundant atmospheric pollen types in their studies. Findings from this study agree well with Essien and Agwu (2013) who reported that pollen of *Syzygium guineense* and Combretaceae were abundant in the atmosphere of their study location. The atmospheric dominance of Poaceae pollen at the study sites is supported by Njokuocha (2006), Essien and Agwu (2013), Adeniyi *et al.* (2014) and Ezike *et al.* (2016) who previously observed the predominance of Poaceae pollen in their respective studies.

However, there were variations in the abundance of airborne Poaceae pollen in the locations over the study period (Tables 1 and 2). Essien and Aina (2014) cited Suphioglu *et al.* (1992), stating that airborne Poaceae pollen

consists of allergens capable of releasing microscopic particles into the atmosphere after dehiscence. The incidence of atmospheric Poaceae pollen is globally most important as a trigger of allergic reactions and has been implicated in pollinosis, as remarked by Taketomi *et al.* (2008). Scevkova *et al.* (2015) detected sensitization to Poaceae pollen as most frequent among pollen allergens identified in the atmosphere of Bratislavia, Slovakia. Galant *et al.* (2010) reported higher prevalence of allergic subjects with positive responses to grasses (Poaceae) compared with weeds, trees, molds and other sources of aeroallergens in California, U.S.A. Singh and Dahiya (2008) carried out a clinico-immunological survey in different parts of India. In their survey, Poaceae was identified as one of the most important allergens in Kanpur and Central India.

The greater recovery of *Nephrolepis* sp. in Kaduna State (Table 1), is similar to earlier findings of Njokuocha (2006) who identified the spore of *Nephrolepis biserrata* as one of the most abundantly recovered fern spore types in his study. The greater recovery of a trilete fern spore in Sokoto State (Table 2) corresponds with the findings of Essien *et al.* (2014) who reported highest abundance of a trilete fern spore, followed by *Pteris dentata* and *Pteris* sp. in their study. The highest recovery of fern spores in October and November at the respective study sites in Kaduna and Sokoto States, agrees with Njokuocha (2006) who recorded higher monthly fern spore concentrations in the respective months of September and November. The recovery of these fern spore types indicates that the study locations are bounded by an established fresh water swamp forest; a parent vegetation of the pteridophytes, inhabited by the represented fern plants in the surrounding environment of the two study sites.

No statistically significant correlation was observed between monthly pollen concentrations and mean values of meteorological parameters at the two study locations (Tables 6 and 8). A positive relationship was observed between monthly pollen concentrations and meteorological parameters including relative humidity and rainfall, but negatively with air temperature and wind speed in Kaduna State (Table 5). This is in agreement with Ezike *et al.* (2016) who reported that monthly pollen load was positively related with relative humidity but negatively with rainfall, wind speed and air temperature. On the other hand, a negative relationship was observed between monthly pollen concentrations and meteorological parameters including relative humidity and rainfall, but positively with air temperature in Sokoto State (Table 7). This is similar to the findings of Abdulrahaman *et al.* (2015) who earlier reported that monthly pollen concentrations were positively related with temperature. Ajikah *et al.* (2015) recorded a negative relationship between monthly pollen load and relative humidity. Njokuocha (2006) also found that monthly pollen load were positively related with temperature but negatively with rainfall. It is expedient to know that an inverse meteorological relationship existed between monthly pollen concentrations of the two locations during the study period (Tables 6 and 8).

Airborne pollen of some plants identified in the immediate vegetation of the two locations were recovered in this study. In Kaduna state, parent plants of the recovered pollen types of *Alchornea laxiflora, Tridax procumbens,*

Pinus caribaea, Albizia sp., *Acacia* sp., Poaceae, Fabaceae, Asteraceae and Cyperaceae, can be identified in the immediate vegetation of the study site. Other enumerated plants including *Pennisetum* sp. and some unidentified grass species belong to Poaceae; *Cyperus* spp. belong to Cyperaceae; *Ageratum conyzoides* belong to Asteraceae (Table 3). In Sokoto state, parent plants of the recovered pollen types of *Tridax procumbens* and Poaceae can be identified in the surrounding vegetation of the study site. (Table 4). These findings are supported by Njokuocha (2006) and Adeonipekun (2012) who observed that pollen from the local vegetation of their sampling areas were considerably recovered in their respective studies. This however confirms a remarkable relationship between the recovered airborne pollen spectra and plants identified in the surrounding vegetation of the study locations.

Conclusions

Pollen peak period from October to March is designated as high risk period for pollen hypersensitive individuals at the study sites in Kaduna and Sokoto states respectively. The results have shown that pollen allergy sufferers in these study locations are exposed to considerably similar types of atmospheric pollen grains, consequent of which they may experience same allergic conditions, including allergic rhinitis, atopic dermatitis among others in these locations. Further clinical studies on the allergenicity of preponderant airborne pollen grains would guide health care providers in making clinical diagnosis and aid in the treatment of patients reporting for pollen allergy in Nigeria. It will also help pollen allergy sufferers to identify plants producing allergenic pollen in their environment and adopt prophylactic measures against this menace.

Acknowledgements

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